

Smart 3-D Subsurface Contaminant Characterization at the BGRR Decommissioning Project

John Heiser, Paul Kalb, Terrence Sullivan, Lawrence Milian,
Brookhaven National Laboratory
Upton, NY 11973-5000

ABSTRACT – *The Brookhaven Graphite Research Reactor is currently on an accelerated decommissioning schedule with a completion date projected for 2005. The accelerated schedule combines characterization with removal actions for the various systems and structures. A major project issue involves characterization of the soils beneath contaminated Below Grade Ducts (BGD), the main air ducts connecting the exhaust plenums with the Fan House. The air plenums experienced water intrusion during BGRR operations and after shutdown. The water intrusions were attributed to rainwater leaks into degraded parts of the system, and to internal cooling water system leaks.*

If the characterization could provide enough information to show that soil contamination surrounding the BGD is either below cleanup guidelines or is very localized and can be “surgically removed” at a reasonable cost, the ducts may be decontaminated and left in place. This will provide significant savings compared to breaking up the 170-ft. long concrete duct, shipping the projected 9,000 m³ of waste off-site and disposing of it in an approved site.

The focus of this Department of Energy Accelerated Site Technology Deployment (DOE ASTD) project was to determine the extent (location, type, and level) of soil contamination surrounding the BGD. A suite of innovative characterization tools was used to complete the characterization of the soil surrounding the BGD in a cost-effective and timely fashion and in a manner acceptable to the stakeholders. A state-of-the-art perfluorocarbon tracer (PFT) technology was used to screen the BGD for existing leak pathways and thus focus the characterization on potential contamination “hot spots.” Once pathways were identified, the sampling and analysis plan was designed to emphasize the leaking areas of the duct and perform only confirmatory checks in areas shown to be leak-free. A small-footprint Geoprobe® was used to obtain core samples and allowed sampling in areas surrounding the BGD that were difficult to access. Two novel, field-deployed, radiological analysis systems (ISOCs and BetaScint™) were used to analyze the core samples and a three-dimensional (3-D) visualization system facilitated data analysis/interpretation for the stakeholders. All of the technologies performed as well or better than expected and the characterization could not have been completed in the same time or at the same cost without using this approach.

A total of 904 BGD soil samples were taken, evaluated, and modeled. Results indicated that contamination was primarily located in discrete areas near several expansion joints and underground structures (bustles), but that much of the soil beneath and surrounding the BGD was clean of any radiological contamination.

One-year project cost savings are calculated to be \$1,254K. Life cycle cost savings, resulting from reduction in the number of samples and the cost of sample analysis, are estimated to be \$2,162K. When added to potential cost savings associated with decontaminating and leaving the BGD in place (\$7.1 to 8.1M), far greater overall savings may be realized.

I. INTRODUCTION AND BACKGROUND

Located at Brookhaven National Laboratory (BNL), the Brookhaven Graphite Research Reactor (BGRR) was the world's first nuclear reactor dedicated to the peaceful exploration of atomic energy. It operated from 1949 – 1968, when the fuel was removed and the facility was placed in “safe storage” mode. The final

decontamination and decommissioning (D&D) process was initiated in 1999 and is scheduled for completion in 2005. An accelerated schedule was developed that combines characterization with removal actions for the various systems and structures. Before D&D work on a section of the BGRR facility begins, contaminant characterization is conducted to determine the types and amounts of contaminants present. The

data are then used for project planning, including decisions affecting the extent of removal, waste designation, and health and safety plans. Additional information on the D&D of the BGRR can be found at <http://www.bnl.gov/bgrr/> and at <http://www.dne.bnl.gov/ewtc/d&d.htm>.

The BGRR was air cooled, powered by five large fan motors. Cooling air was brought in through two filtered plenums, flowed through and around the reactor core, through a set of exhaust ducts containing filters, and finally out through the 320-foot high exhaust stack. Contamination inside the Below Grade Ducts (BGD) resulted from the deposition of fission and activation products from fuel failures during reactor operations. The air plenums experienced water intrusion both during BGRR operation and in the 30 years since it has been shut down due to rainwater intrusion and internal cooling water system leaks. Samples of the water and sludge deposited in the ducts were analyzed indicating the presence of Cs-137, Sr-90 (> 90% of the total activity), and other isotopes. Based on water level measurements and watermarks within the ducts, it was determined that the contaminated water leaked out of the ducts, thus potentially contaminating large volumes of soil beneath the BGD. If the leakage were wide spread, the BGD structure itself would require removal to remediate the contaminated soil beneath. However, if the subsurface contamination is limited to discrete locations, the soil may be "surgically removed" so that the BGD structure could be decontaminated (internally) and left in place, resulting in large potential cost savings. The recent draft Engineering Evaluation/Cost Analysis (EE/CA) estimated these savings would range between \$7.1 to 8.1M compared with removal of the BGD. The primary goal of this Accelerated Site Technology Deployment (ASTD) project, sponsored by the Department of Energy Office of Science and Technology Decontamination and Decommissioning Focus Area was to determine the extent of contamination beneath the BGD and determine if the BGD could be left in place.

Figure 1 shows the schematic plan view of the BGRR duct facilities along with a side view representation of the ducts. The underground air ducts (plenums) are approximately 170 feet long, running from Building 701 (Reactor Building) to the above-ground joint. Each of the north and south exhaust air-plenums are approximately ten feet wide and fourteen feet high. The ducts are

constructed of one-foot thick reinforced concrete lined with two layers of carbon steel. The steel liners make up the primary and secondary ducts. The primary duct provided cooling air for the reactor; the secondary duct maintained counter-flow cooling to prevent overheating of the concrete. Both of the primary ducts are highly contaminated. Most of the contamination is confined to the primary ducts, but corrosion of the primary ducts has lead to some contamination of the secondary ducts. Leakage of water from the secondary ducts is likely to have resulted in contamination of the surrounding soil.

The main air duct has two expansion joints and three minor joints, which were considered to be the most likely points for the release of contamination from the ducts to the environment. In addition, the concrete ducts are over forty years old. There is no certainty that these old, large, cast concrete structures have not cracked, yielding new pathways for contamination release. The leak pathways out of the secondary ducts had to be defined in order to develop a soil sampling plan that was economically feasible (compared to cost for removal of the BGD) and fit the scheduling requirements.

As can be seen in Figure 1, the ducts are very large and a huge volume of soil surrounds the BGD. To adequately define the extent of contamination using conventional baseline techniques would require analysis of all the soil immediately surrounding the BGD. Based on soil characterization data for the Canal House soils (which are immediately adjacent to the BGD soils), core samples would be needed every three feet along the sides of the duct as well as below the duct. Cost for outside laboratory analysis of that many samples would be exorbitant and the turn around time would force an unacceptable delay in the remediation. In addition, much of the soil surrounding the BGD is in hard-to-access areas (i.e., under the duct) so it would be difficult to obtain cores. Thus, to adequately define the contamination using conventional means would be cost prohibitive and would deplete much of the cost savings obtained by leaving the ducts in place.

Under this ASTD initiative, a suite of innovative characterization tools was used to complete the characterization of the soil surrounding the BGD in a cost-effective and

timely fashion and in a manner acceptable to the stakeholders. The tools consisted of a tracer gas leak detection system that was used to define the gaseous leak paths out of the BGD (and hence worst case scenario for water leakage) and optimize soil characterization studies, a small-footprint Geoprobe® to reach areas surrounding the BGD that were difficult to access, two novel, field-deployed, radiological analysis systems (ISOCS and BetaScint™) and a three-dimensional (3-D) visualization system to facilitate data analysis/interpretation for the stakeholders.

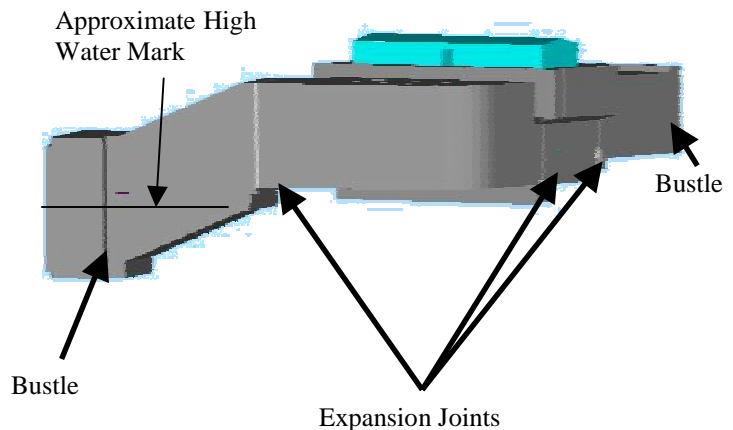


Figure 1. Plan and side view of Below Grade Ducts

II. TECHNOLOGY DEPLOYMENTS AND COST SAVINGS

II.A. Identifying Potential Leak Pathways Using Perfluorocarbon Tracers

As part of the overall characterization efforts, a state-of-the-art gaseous perfluorocarbon tracer (PFT) technology developed at BNL was applied to determine the gas leak pathways from the ducts. The use of PFTs determined which of the suspect areas were in fact leaking (and the relative magnitude of the leaks), but more importantly determined that no additional areas of the duct were leaking (e.g., due to cracks in the concrete duct). Another advantage of using PFTs was that they allowed elimination of some of the suspect contamination pathways by determining that they were not leaking. Confirmatory sampling was performed in these areas, saving considerable funds.

Overall, the PFT technology allowed the regulators and stakeholders to have confidence in the sampling scheme that emphasized suspect/known leak pathways and used confirmatory sampling elsewhere.

PFTs allow locating and sizing of leaks at depth, have a resolution of fractions of an inch, and have been used in a variety of soils. BNL has demonstrated the PFT technology for use as a leak detection system for contaminant transport barriers such as subsurface containment barriers and cap/cover systems on waste sites and documented their benefits over conventional

tracers.^{1,2,3} The use of PFTs to check for leaks in the BGD is a logical extension to previous environmental applications (e.g., integrity verification in barriers).^{3,5,6}

Because PFTs can be detected at extremely low levels (e.g. parts per quadrillion), very small leaks are easily identified. Leaks in the BGRR underground ducts were located by injecting the PFTs inside of the ducts and monitoring for the tracers outside of the ducts. Where and how much of the tracer was detected on the monitoring side of the ducts determined the location and size of the leaks. Larger openings in the ducts mean that greater concentrations of tracer are transported out more rapidly. The injection and monitoring of the tracers were accomplished using conventional low-cost monitoring methods, such as multilevel sampling ports placed using cone penetrometer (Geoprobe®) techniques.

The PFTs were introduced into the interior volumes of the BGD through the secondary air system outer cooling channels and distributed via a closed-loop circulation system. This allowed for recirculation of the tracer. The rate of gas injection was determined based on the volume of the cooling channel, the source concentration of the tracer (ranged from 100 to 1000 ppm), expected diffusion rates, and engineering assumptions about the cross-talk between the primary duct and reactor pile volumes with the secondary cooling ducts. Tracer injection rates ranged from 0.2 ml/min to 22 ml/min. The target goal for the interior concentration was determined through modeling based on the flow rates, injection concentration and volume, and plenum volumes. The cooling channel PFT concentration was monitored at least daily during the duration of the injection and generally ranged from 10 to 100 ppb. The North and the South Ducts were isolated from each other. Inlet and outlet flexible ducting was installed to provide separate circulation loops for the North and South Ducts (see Figure 1) to allow different tracers to be circulated in each duct. This yielded data that was specific for each duct and helped to more accurately define leak pathways. The injected PFTs were monitored outside the ducts through a series of multi-level gas sample ports in close proximity to the ducts. Monitoring wells were placed every ten feet along both sides of the ductworks and topside along the central axis of each individual duct. A total of 42 wells with 131 sampling points were installed (Figure 2). This diagram depicts the underground ducts from the secondary bustle to the coolers (to see how this fits into the reactor layout and overall air-ducts see Figure 1).

The injection continued for seven to ten days and the concentration of tracer was monitored at regular sampling intervals.

Two injection tests were performed. The first, termed the preliminary injection, was designed to determine the degree of leakage and cross-talk within the duct system and confirm the appropriate tracer gas flow rates. The second was the actual leak test, designed to determine the leak paths from the BGD. The data from the

preliminary test showed transport to be fairly rapid. For this reason, full sampling of the external ports was performed on alternating days starting 24 hours after injection began. Sampling continued for nine days at which time a consistent picture of the leak pathways from the ducts emerged, as judged through analysis of the data. The data interpretation was conducted with C Tech's EVS-PRO.⁴ EVS-PRO unites interpolation, geologic modeling, geostatistical analysis, and fully three-dimensional visualization tools into a software system developed to evaluate environmental contamination issues.

The PFT data were analyzed to determine gas leak locations. This, in turn, allowed determination of what soil regions under or adjacent to the ductwork were to be emphasized in the soil characterization process. Knowledge of where gaseous tracers leaked from the ducts yielded a conservative picture of where water may have moved out of or into the BGD. The regions with the highest chance of releasing contamination to the surrounding soils are the locations determined by the PFT tests that are along the bottom or below the high water mark in the ducts. Equally as important, the PFT data showed which areas of the duct were not leaking and, therefore, required only a limited number of confirmatory soil explorations.

Figure 3 (left) presents representative data for the tracer PMCP at the South Duct. Evidence of PMCP in the surrounding soils indicates a leak pathway from the internal duct. Sample concentrations are color coded with red denoting the highest concentration and blue the lowest. The red to orange areas near the bustle (left-hand side) indicate that a substantial hole exists in this area of the duct. Regions of minimal or no leakage are depicted in blue. The data clearly indicate that there are substantial areas where leakage is minimal. If a region is not susceptible to gas leakage, it is not susceptible to water leakage.

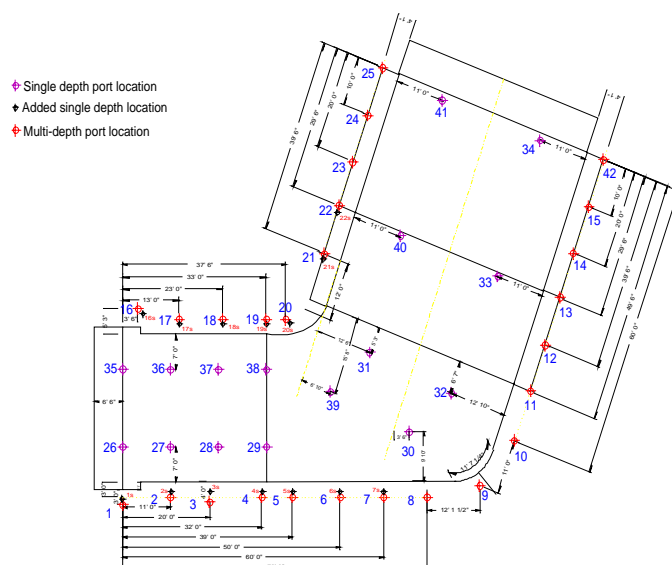


Figure 2. Plan view of monitoring ports for the PFT leak test

Figure 3 (right) presents a representative data set for the tracer o-PDCH at the North Duct on February 14th. There are several indications of leaks at this duct and the concentrations are typically higher than on the South Duct. The peak concentrations again indicate a substantially sized flaw in the duct allowing release of the gas. High values (green to red) were detected at the expansion joints on either side of the filter house and some at the bustle (green to cyan, right-hand side).

The data analysis clearly indicates major leakage at the bustle area (nearest reactor building). Significant leaks are also seen near most of the expansion joints with greater leakage occurring on the north side. Much of the South Duct remains “clean” with only low concentrations of tracers present. The North Duct shows greater gas transport from the duct to the soil with high concentrations at each of the expansion joints. The leak profile for both ducts was stable throughout the injection test providing confidence that the information provided by the test is reliable. In addition, the North Duct leak profile of o-PDCH (second test) is similar to that found by PDCB (first test). Similarly, the South Duct leak profile of PMCP (second test) is

similar to that found by PMCH (first test). This provides further confidence that all leak pathways from the north plenum to the surrounding soils have been defined. Examination of the concentration profiles for all tracers showed the same leak locations on both ducts.

The information gained in the PFT Tracer Gas Study was used to guide and optimize the soil characterization strategy for the BGD Sampling and Analysis Plan (SAP). Combining this information with process knowledge permitted an improved sampling plan to be developed. The SAP was designed to coincide with the identified gas leaks. This allowed the regulators and stakeholders to have confidence in the sampling scheme as it emphasized suspect/known leak pathways. Another advantage to using PFTs is that they were able to eliminate some of the suspect contamination pathways by determining that they were not leaking. In these regions only confirmatory type sampling was conducted, saving considerable funds and time. A complete reporting of the tracer study can be found in “Characterization of Leak Pathways in Below Grade Ducts of the BGRR Using Perfluorocarbon Tracers”.⁷

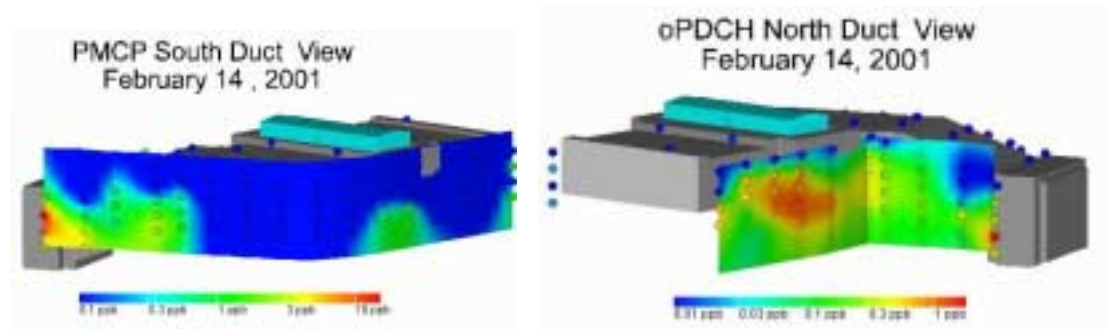


Figure 3. Concentration profiles for separate PFT tracers in the South and North Ducts

II.A.1. Comparison of Leak Test Results to Contamination Profile

Once the leak paths were found and the SAP completed, core samples were taken from around the BGD. The cores were taken using a Geoprobe® Model 54 LT (tractor mounted) continuous push, soil-probing unit with a macro core soil sampling system. The tracked penetrometer allowed rapid deployment and use in cramped or tight areas and on uneven terrain and is discussed later. The cores were then surveyed in the field for gamma-emitting radionuclides using the ISOCS and for Sr-90 using the BetaScint™. This equipment is described in greater detail in the Cost and Performance Report.¹ The data was input into the Environmental Visualization System for comparison to the PFT data and to provide a clear and concise 3-D picture of the location and extent of contamination for presentation to stakeholders.

The real measure of success for the tracer study is how well the PFT leak pathway data conforms to the contamination distribution determined from analysis of soil samples. To this end, the contamination distribution determined from deep soil samples was correlated to the tracer gas concentrations in the soil during the leak test. None of the areas determined to be leak-free in the tracer study showed Cs-137 contamination above background. As shown in Figure 4, the hot spots (contamination above preliminary cleanup goals) all coincide with the largest leaks seen with the use of the PFTs. This is positive confirmation that the PFT study was successful in determining all the possible leak pathways. The excellent correlation of PFT leaks to contamination distribution, the stability of the PFT

concentration profiles over the course of the leak test, and repeatability of the PFT findings (as determined from the multiple tracers all having similar profiles) are very strong evidence that the tracer technology met all goals and performed according to expectations.

II.A.2. PFT Cost Savings

To determine potential cost savings realized by using the PFT technology, the cost of sampling following the actual SAP (which was premised upon the tracer study results) is compared to the cost of sampling if the tracer study were not available (following an assumed SAP with little or no knowledge of leak paths). The tracer study allowed for reduced sampling along the joints that showed little leakage and tight sampling along the bustle where large leaks were found. Based on the Canal House characterization, which is adjacent to the ducts, soil contamination occurred in narrow, discrete, vertical bands, i.e., little or no horizontal spreading occurred. Thus, to identify contaminated soil at joints known to have leaked (e.g., the bustle) required sampling on 2.5-foot intervals across the joint. At the remaining joints, two boreholes were placed at each joint, one bisecting the North Duct and one bisecting the South Duct.

In all, the SAP called for 904 samples from 32 boreholes to be taken adjacent to the ducts. This number excludes surface soil samples and blanks, which would be needed with or without the tracer study. Since the cost of these samples would be the same for both sampling schemes, they are not considered in the remainder of this analysis. The SAP called for core samples to be taken from 18" below grade level (or from the bottom of the ducts) to refusal or the water table, whichever came first. The SAP also required

additional samples to be taken whenever contamination was encountered. The additional samples were used to bound the extent of the contamination. In either case, the additional boreholes needed to bound the contamination would remain the same (as the “plume” of contamination is fixed and independent of the characterization). Again, these extra samples

Ducts) under the joints and two in the soil adjacent to the joint (one at the north side and one at the south side).

Between joints exploratory sampling would be used. Based on the Canal House data no more than 10-foot spacing would be acceptable and less than 5-foot spacing would be neither

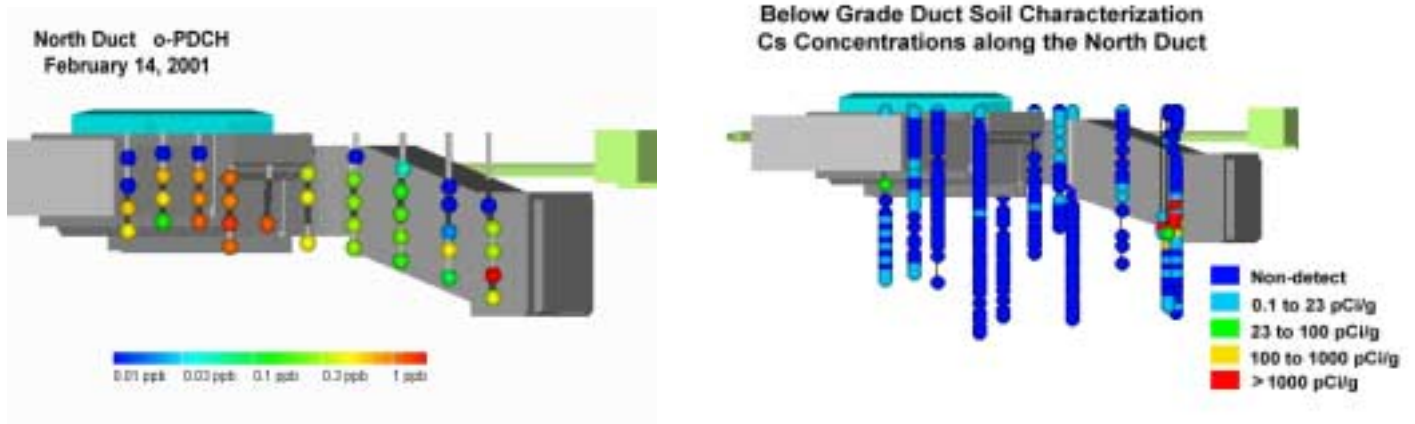


Figure 4. Comparison of PFT results and soil characterization along and below the North Duct

taken to bound the contamination are not considered here, as they are equivalent in both sampling schemes.

Without the tracer study, the soil characterization would be conducted “blind”, i.e., there would be no information about areas that were clean and did not require extensive characterization. It would seem obvious that the joints would be suspect and should be investigated, but the integrity of the rest of the duct would be unknown. This would require soil sampling beneath the ducts (without the tracer study the ducts would have to be removed) in a grid pattern tight enough to find the contamination with reasonable certainty. Since little would be known about leakage at the joints, they would all require close sample spacing, as per the SAP at the bustle. This would require 10 boreholes (five each for the North and South

economically feasible nor schedule compatible. 10-foot spacing for exploratory confirmation between joints was assumed for this comparison as the minimum acceptable to the stakeholders (if contamination were found, bounding characterization would be required). Table I summarizes the sampling requirements of the two cases.

Total costs, summarized in Table II, for the two characterization schemes include materials, cost to collect the samples, cost to analyze the samples, and project management costs (management, health and safety, trades, etc). Use of the PFTs to define the potential leak pathways results in a cost savings of \$849K.

Table I. Borehole and Sample Requirements for the 3 Soil Characterization Alternatives

	Using PFT Tracer Gas Study	Alternative (10 foot spacing)
Boreholes Needed	32	98
Number of Samples	904	2542

Table II. Comparisons of Characterization Costs Using the Tracer Gas Study and Baseline Approaches ^{a,b}

Description	Using PFT Tracer Gas Study Cost (\$)	Alternative Cost (\$)	Cost Savings (\$K)
Materials	1,500	2,000	0.5
Sample collection	92,800	284,200	191
Gamma analysis	227,800	640,600	413
Beta analysis	180,800	508,400	328
Project Management	64,000	196,000	132
Tracer Study	215,000	N.A.	(-215)
Total	781,900	1,631,200	849
a) Based on first year costs			
b) Assumes baseline analytical costs for all scenarios			

Sample collection costs mainly consisted of collection of core samples via Geoprobe[®]. Some minor incidentals, such as chain of custody paperwork, are included in the project management costs. The cost for materials and operation of a Geoprobe[®] and a two-man crew was \$1,450 per day. Each borehole consisted of 23 to 34 samples and on average required 2 workdays to complete. The SAP required 32 boreholes for collection of samples adjacent to the BGD at a cost of \$92.8K. The baseline minimum characterization would have required 98 boreholes at a cost of \$284.2K. It must also be noted that the baseline sampling would have taken an additional 130 workdays or 26 calendar weeks.

Characterization included gamma, beta, and occasional RCRA analyses. Cost for offsite laboratory analysis is \$252 per sample for gamma analysis and \$200 per sample for beta analysis. While actual analytical costs (using ISOCS and BetaScint[™]) for this project were lower, baseline characterization costs (outside laboratory) are used here to determine savings due to the PFT Tracer Gas Study alone (ASTD savings). The 904 samples from the SAP would cost \$227.8K for gamma analysis and \$180.8K for beta analysis for a total of \$408.6K. The alternative characterization requires 2542 samples and would cost \$640.6K for gamma analysis and \$508.4K for beta analysis, for a total of \$1,149,000.

Project management costs are apportioned based on the length of the characterization

process. A fixed cost (\$1000 per day) is applied based upon the sample collection rate. It is assumed laboratory analysis would keep up with sample collection. For the ASTD alternative, this amounts to \$64,000. For the baseline alternative, project management costs are estimated at \$196,000.

The cost of the tracer study must also be considered. The materials costs amounted to \$5K. The tracer analysis of ~1200 gas samples was performed by an onsite laboratory at a cost of \$90K. Personnel cost for component installation, tracer preparation/injection, monitoring, and data reduction was \$120K. The total cost for the PFT study was \$215K and is deducted from the cost savings.

A life cycle cost analysis (as per standardized DOE-EM guidelines) is presented in the ASTD Cost and Performance report.¹ The PFT technology is a unique system that has no real baseline equivalent. Therefore, the only comparison that can be made is between the characterization of the BGD with and without PFTs. The analysis compares the alternative characterization to the characterization performed according to the SAP. Life cycle cost savings are calculated to be \$849K with a ROI of 395%.

II.B. Small Footprint Geoprobe[®]

The small footprint Geoprobe[®] was used to install PFT wells and take soil samples, but was most useful in accessing areas that would otherwise require terrain or structural alterations.

The cost savings associated with the Geoprobe® are difficult to quantify because it is hard to estimate how long it would take to restructure the site (or alter characterization plans) to make it fully accessible by the conventional truck-mounted probing systems. While cost savings over conventional probing technologies were realized, these costs were not included in overall project cost savings due to these uncertainties.

II.C. In-Situ Object Counting System (ISOCs)

The ISOCs gamma spectroscopy system again proved extremely valuable to the BGRR D&D project. In the second ASTD deployment of this technology at the BGRR, the system was used as a mobile field laboratory to provide rapid, high-quality analyses of gamma-emitting radionuclides. Every soil sample collected was analyzed using ISOCs (with a percentage also being sent to an independent offsite laboratory for confirmation). The gamma spectroscopy data from ISOCs was then input into the EVS-PRO software to provide a profile of the contamination around the BGD.

The initial ISOCs deployment at BGRR (FY 99 ASTD) provided the performance comparison of ISOCs with traditional laboratory analysis⁸ and demonstrated good correlation between conventional gamma analysis in sensitivity, accuracy, and precision, while providing considerable cost savings.

Including blanks and bias samples, approximately 1700 samples were analyzed by ISOCs over the course of 6 months. This included the ~900 deep soil samples taken from around the BGD, an additional 500 soil samples taken from near the BGD, and 300 structural samples (concrete core, steel, aluminum, asphalt, and other miscellaneous samples). These samples were taken when coring through the ducts to characterize below the ducts and as part of the characterization of the ducts themselves.

II.C.1. ISOCs Cost Savings

Evaluation of costs considered only the tangible savings associated with ISOCs. In addition, rapid turn-around of samples allowed optimal use of equipment and manpower. No schedule delays occurred while waiting for offsite laboratory analyses. Rapid turn-around (measured in days) for offsite laboratories is available at additional cost. ISOCs was able to

handle last-minute sample analysis demands without a delay in getting the data into the EE/CA.

The conventional baseline method requires shipping samples to an off-site laboratory (with a one to four week turn-around) at a total cost of about \$252/sample (based on current contract values). Based on data evaluated for the previous ISOCs deployment at BGRR, ISOCs analysis cost for *ex-situ*, field laboratory analyses is about \$76 per sample. By agreement with the regulators, BNL sent a percentage of the samples off-site for confirmatory analysis. This was done to assure the regulators that data from ISOCs was equivalent to conventional gamma spec data. The SAP called for confirmation, by an outside laboratory, of 30% of the samples that fell within 0.5 to 1.5 times the cleanup goal.

Total cost of analysis of the 1700 samples was \$130K. The cost for off-site analysis of 1700 samples without the ISOCs would have been \$428K. Total one-year cost savings attributable to ISOCs are \$297.7K (excluding capital investment since this was a secondary deployment). Cost savings over the five-year life are calculated to be \$842K with a ROI of 96%.¹

II.D. BetaScint™

This is also the second deployment for BetaScint™ at the BGRR. BetaScint™ was used to survey soil samples for Sr-90. The performance comparability of the BetaScint Industries Strontium-90 fiber optic detector to baseline technologies was discussed in the final report for the first ASTD deployment.⁸ As with ISOCs, BetaScint™ compared very favorably to conventional Sr-90 analysis. In all, 725 samples were analyzed using the BetaScint™ system. The data from BetaScint™ was input into the EVS-PRO software to provide a profile of the Sr-90 contamination around the BGD.

Quantification of Sr-90 using conventional EPA laboratory methods typically takes a minimum of two weeks (accelerated turn-around/costly) to a month (standard turn-around). After sample preparation, including sieving and spreading soil samples on trays, the BetaScint™ system produces accurate and precise results with a quick turn-around time (approximately 5-10 minutes) and detection sensitivity of approximately 1 pCi/gram.

II.D.1. BetaScint™ Cost Savings

The cost of conventional baseline Sr-90 analysis (including transportation) is approximately \$200/sample and usually requires 2 to 4 weeks. BetaScint™ analyses cost about \$50/sample so the cost of 725 samples was \$36K. The SAP called for confirmation, by an outside laboratory, of 30% of the samples that fell within 0.5 to 1.5 times the cleanup goal. Of the 725 samples, 7 fell within this range requiring 2 to be sent off-site for confirmatory analysis at a cost of \$500. The total cost to analyze the 725 samples was \$36.5 (\$36K + \$0.5K). If all 725 samples had been sent for off-site analysis the cost would have been \$145K. Therefore the total one-year cost savings due to the use of BetaScint™ were \$108.5 (excluding capital investment since this was a secondary deployment). Cost savings (with a five year lifetime) are calculated to be \$471K with a ROI of 80%.¹

II.E. Three-Dimensional Visualization Software

The EVS-PRO software allows a clearer and more intuitive presentation of characterization data to stakeholders. Stakeholders are often inundated with tables of numbers, statistics, and charts and expected to accept conclusions about data at face value. Public meetings give site owners a short time frame to convince stakeholders that the proposed cleanup is adequate and that characterization data supports the proposal. If the data and trends cannot be made clear and understandable to the layperson then the data may prove useless. Data presented in a clear, concise, and intuitive manner allows the stakeholder to be quickly educated about the remediation and facilitates informed decisions regarding the remediation.

The EVS-PRO software was used to analyze and provide 3-D visualizations of the data from the PFT leak study and the radiological contamination data obtained from the soil samples. In the PFT study approximately 1200 samples were collected over 2 weeks. The EVS-PRO software proved very easy to use and made interpretation of the data clear and simple. It is easy to see where leaks are located on the ducts (Figure 3). The visualization also highlights the spatial correlation among the data and makes it clear that some locations show tracers in elevated concentration but that those tracers are “drifting” over via diffusion. The color contours are easy

to correlate to a leak. It would be extremely difficult to determine the high, medium, and low tracer concentrations and then to match them up to locations along the ducts with 131 data points for each day of the PFT test.

EVS-PRO also simplifies data interpretation even further by creating 3-D movies and virtual 3-D images that may be viewed on a monitor. This allows all sides of the duct to be viewed by the user. A movie was prepared of the BGD that begins with the north side of the BGD and slowly rotates the ducts to show the south side and top views. This gives the audience the feel of “walking” around the ducts and looking at the leaks.

The EVS-PRO output from the tracer study, including the movie, was presented at a stakeholders meeting to discuss the characterization efforts at the BGRR and was very well received. The public acceptance of the accuracy of knowledge of leak pathways from the ducts appeared high. The data was also presented to regulators as part of the SAP approval process. The regulators expressed a high degree of satisfaction with the data presentation and the SAP was approved. EVS-PRO visualizations were generated for the soil contamination profile surrounding the BGD and were incorporated into the draft EE/CA.

The cost evaluation for the EVS-PRO software cannot be readily quantified. EVS-PRO software is an enabling technology that improves communication among data analysts, program managers, regulators, and other stakeholders. EVS-PRO's power is in its ability to transform large quantities of data into an effective three-dimensional, spatial presentation that can be clearly understood by all stakeholders. This presentation of the characterization data is more effective and makes it easier for all parties to understand the nature and extent of the problem and come to agreement on the next phase of the remediation project.

III. CONCLUSIONS

A suite of innovative technologies was deployed to characterize the radionuclide levels (Cs, Sr, Co, and Am) in soils around and beneath the BGRR. All of the technologies performed as well or better than expected. The characterization could not have been completed in the same time or at the same costs without the use of these technologies. The major advantages of this approach include:

- The use of PFTs to define potential radionuclide release pathways from the BGD resulted in lower soil sample density and provided greater confidence that leaks were not missed in comparison with the baseline approach.
- The use of the track-mounted Geoprobe[®] permitted samples to be collected where other techniques would be inadequate (between electrical duct and the BGD), led to reduced sampling costs, and provided the flexibility to sample as needed when contamination was detected.
- The ISOCS and BetaScint[™] detection systems led to sharply reduced sampling

costs compared with conventional baseline analyses and provided rapid turn-around, which was used to define new sample locations required to bound the extent of contamination.

- The use of EVS-PRO to visualize and interpret the data provided an effective method to communicate results with various stakeholder groups.

Potential cost savings associated with deployment of these technologies are summarized in Table III. Reported cost savings are based on the quantity of conventional baseline characterization samples that would have been required without the innovative technologies deployed under this ASTD project. When considered together, this suite of innovative technologies is estimated to have saved more than \$1.2M in the first year alone. When using the DOE Life Cycle Cost methodology, the cost savings grow to \$2.1M. The estimated cost savings associated with leaving the BGD in place (\$7.1 to 8.1M) boosts potential cost savings to between \$9.2 and \$10.2M.

Table III. One-Year Estimated Cost Savings Associated With Deployment of the ASTD Alternative Characterization Technologies

Technology	One-Year Cost Savings ^a	Life- Cycle Cost Savings ^a
Perfluorocarbon Tracer Leak Detection	\$849,000	\$849,000
Geoprobe [®] LT-54	N.C.	N.C.
ISOCS Gamma Spectroscopy	\$297,000	\$842,000
BetaScint [™] Sr-90 detection	\$108,500	\$471,000
EVS-PRO Visualization Software	N.A.	N.A.
Total Savings due to ASTD Technologies	\$1,254,500	\$2,162,000
a) N.C. = not computed; N.A. = not applicable		

IV. REFERENCES

1. J. HEISER, P. KALB, T. SULLIVAN, and L. MILLIAN, Smart 3D Subsurface Contaminant Characterization at the BGRR Decommissioning Project, Accelerated Site Technology Deployment. Cost and Performance Report. Brookhaven National Laboratory. Inpress (2002).
2. T.W. D'OTTAVIO and R.N. DIETZ, Radon Source Rate Measurements using Perfluorocarbon Tracers. *Indoor Air '87, 4th International Conference on Indoor Air Quality and Climate*, Berlin, Germany, (1987).

3. J. HEISER, T.M. SULLIVAN, Using Perfluorocarbon Tracers For Verification Of Cap And Cover Systems Performance. Brookhaven National Laboratory, Upton, New York, November 2001, BNL-52647, (2001).
4. T. SULLIVAN, A.Q. ARMSTRONG, A.B. DINDAL, R.A. JENKINS, J. OSLEEB, and E.N. KOGLIN, "Environmental Technology Verification Report. Environmental Decision Support Software. C Tech Development Corporation, Environmental Visualization System (EVS)," EPA/600/R-00/047, (2000).
5. J. HEISER and B.P. DWYER, Summary Report on Close-Coupled Subsurface Barrier

Technology - Initial Field Trials to Full-Scale Demonstration. Brookhaven National Laboratory, Upton, New York, September 1997, BNL-52531, (1997).

6. T.M. SULLIVAN, J. HEISER, A. GARD, and G. SENUM, Monitoring Subsurface Barrier Integrity Using Perfluorocarbon Tracers *ASCE Journal of Environmental Engineering*, **124**:6 (1998).

7. J. HEISER, T.M. SULLIVAN, P. KALB, L. MILIAN, C. NEWSON and M. LILIMPAKIS, Characterization of Leak Pathways in Below Grade Ducts of the BGRR Using

Perfluorocarbon Tracers. Brookhaven National Laboratory, Upton, New York, April 2001, BNL-52629, (2001).

8. P.D. Kalb, L. Milian, L. Luckett, D. Watters, K. M. Miller and C. Gogolak, Deployment of Innovative Characterization Technologies and Implementation of the MARSSIM Process at Radiologically Contaminated Sites, FY2000 Program Document Compilation, Brookhaven National Laboratory, Upton, New York, May 2001, BNL-52633.